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SEEDING OF BRACKISH WATER IN A SPRAY-FILM EVAPORATOR

by

John E. Jones, Jr.

January 1970

U. S. ARMY MOBILITY EQUIPMENT RESEARCH AND DEVELOPMENT CENTER
FORT BELVOIR, VIRGINIA

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Report 1972

SEEDING OF BRACKISH WATER IN A SPRAY-FILM EVAPORATOR

In-House Task No. 1L013001A91A00

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The Commanding Officer
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Military Technology Laboratory

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SUMMARY

This report covers a study made by the U. S. Army Mobility Equipment Research and Development Center at the Department of the Interior's Roswell Test Facility, Roswell, N. M., investigating the use of crystal-seeding techniques to inhibit the formation of sulfate evaporator scale in a horizontal-tube, spray-film evaporator. The crystal-seeding techniques were tested on this evaporator using raw well water and silica-removed well water. A control test using raw well water without crystal seeding was also conducted.

It is concluded that:

a. Crystal-seeding techniques inhibit the formation of sulfate and alkaline scale in the horizontal-tube, spray-film evaporator.

b. Although the spray-film evaporator was properly designed to recirculate the crystal seeds without excess accumulations in the evaporator, the design of the spray pattern, tube bundle, and slurry separators were not adequate for the task.

c. Piping which carries the slurry must be fitted with ball valves, "tees," and "crosses" because the lines will require rodding whenever the flow stops.

d. The silica-removed well water caused scaling on the evaporator tubes.

FOREWORD

The investigation covered by this report was conducted by the Sanitary Sciences Division, Military Technology Laboratory, U. S. Army Mobility Equipment Research and Development Center, Fort Belvoir, Virginia under In House Task 1L013001A91A00 "Seeding of Brackish Water."

The following personnel were responsible for conducting the study:

General Supervision

LTC P. A. Woolaver, Acting Chief, Military Technology Laboratory.
Richard P. Schmitt, Chief, Sanitary Sciences Division.
Richard J. Gainey, Chief, Water Equipment Branch.

Acquisition and Presentation of Data

John E. Jones, Jr., Project Engineer.
Carl S. Pate, Engineering Technician.

Acknowledgment is made of the cooperation and supporting effort given this investigation by the Office of Saline Water (OSW) of the Department of the Interior.

The following personnel aided materially in the success of the test:

Charles Grua, Manager, Roswell Test Facility.
Robert S. Robinson. Project Engineer, Distillation Division.
Ross Gardner, Plant Superintendent, Burns & Roe Construction Corporation, Roswell Test Facility.

Appreciation is also given to the personnel who operated the unit and collected operating data and to the personnel who made the chemical analyses on the water and scale samples collected.

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SEEDING OF BRACKISH WATER IN A SPRAY-FILM EVAPORATOR

I. INTRODUCTION

1. **Subject.** The purpose of this study was to determine if crystal-seeding techniques could be adapted to prevent scaling when brackish water was being purified in a spray-film evaporator.

2. **Background.** A horizontal-tube, spray-film, vapor-compression distillation unit belonging to the OSW was modified to incorporate crystal-seeding techniques to inhibit the formation of sulfate scale when brackish water was being used. These techniques were previously investigated by MERDC under this in-house project.

Alkaline scales—calcium carbonate or magnesium hydroxide—are controlled in Army distillation units by the periodic addition of acid to the feed water. Sulfate scale, unlike alkaline scale, cannot be controlled by acid.

During sea water distillation, calcium sulfate scale deposits are prevented by maintaining the brine concentration below the solubility limits of calcium sulfate. In order to obtain as much water as possible from a brackish source, however, these waters must be concentrated four or more times—well over the solubility limits of calcium sulfate. The Army has an interest in this problem because the sulfate-scaling type of brackish water is found on all continents; the areas of primary concern are North Africa, Australia, Southern Russia, and the Middle East, where such waters abound. Experience has shown that evaporator scale from brackish water is frequently much greater than from sea water, even though the total dissolved solids in the water are much lower.

Previous work on the Roswell well water (1)* shows that the present Army vapor compression sea-water evaporator cannot successfully distill this type of water. Crystal-seeding techniques using a calcium sulfate slurry showed promise in concentrating this water in a vertical-tube, forced-circulation evaporator (2). This process was built into the OSW Roswell Demonstration Plant.

The theory of crystal-seeding technique using a calcium sulfate sludge has been advanced as the affinity of the precipitating scale-forming compounds for a surface of a compound having a similar crystal structure. This method of scale prevention has been used with success in industrial evaporators.

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*Numbers in parentheses refer to entries in *Literature Cited*, p. 18.

The spray-film distillation uses a brine spray on the outside of the evaporator tubes which condenses the compressed steam inside the tubes (3,4). This process uses a relatively low brine recirculation rate as compared to other recirculation evaporator methods to maintain the effectiveness of the seed crystals. If this system could be adapted successfully to seeding techniques, it would be considered for application to Army distillation equipment to permit use on the high-sulfate brackish water sources. This test equipment was made available to MERDC for test purposes at the OSW Roswell Test Facility, Roswell, N. M. This site (Fig. 1) is noted for its natural sulfate-scaling water.

II. INVESTIGATION

3. **Process Description.** The horizontal-tube, spray-film evaporator vaporizes a portion of the recirculating brine that is sprayed on the outside surfaces of the horizontal-tube bundle. The vaporized water passes through a demister into the suction of the vapor compressor. The compressor raises the pressure and temperature of the vapors. The vapor passes into the horizontal-tube bundle where it condenses, giving up its heat of vaporization through the tube walls to the recirculating brine spray. The flow diagram is shown in Fig. 2.

The horizontal-tube evaporator bundle was made up of 209 tubes of 90-10 copper-nickel, 5/8-inch OD, 18-gauge, 8-foot long, which had an outside surface area of 268 square feet. The first pass had 139 tubes in 10 layers; the second pass had 70 tubes in 5 layers. The tubes were spaced on a 1-3/4-inch-square diamond pattern

Four spray nozzles, Spraying Systems Co. No. 1-1/2 H290WSQ, were mounted 9 inches above the tube bundle and 24 inches apart on a 2-1/2-inch manifold from the recirculation pump. These nozzles were designed to produce a wide-angle full-square pyramid spray pattern. The nozzles, during operation at 205° F and at 21 psig, passed approximately 41 gpm of brine each, at an effective spray angle of about 97°.

The slurry separators used on the unit were two Dorr-Oliver, Inc. Doxie Type P 25-mm cyclones which were piped in parallel. A portion of the recirculation brine was piped from the recirculation pump to the slurry pump and introduced to the separators. The overflow from the separators was disposed of as blowdown brine, while the underflow with its higher slurry circulation was returned to the suction side of the recirculation pump.

The feed water was preheated by two heat exchangers, one cooling the distillate and the other using steam to bring the feed to the inlet temperature of approximately 205° F. Acid was not added; therefore, a deaerator was not necessary.

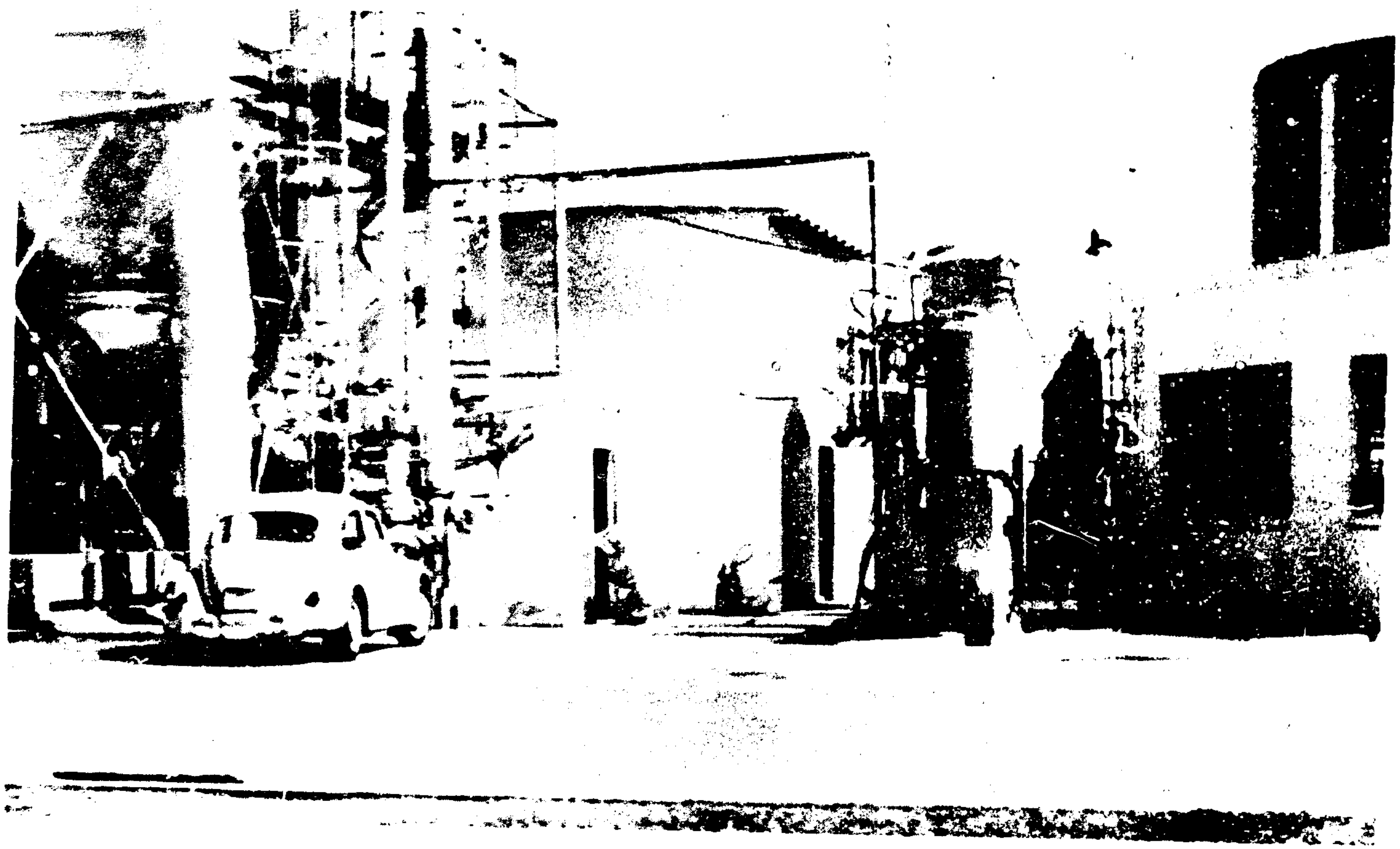

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Fig. 1. Test Site. The horizontal-tube, spray-film evaporator was housed in the larger building in the left center of the picture inside the 1-million-gallon-per-day vapor-compression plant. To the right is the silica removal unit which was used in Test A of the test program.

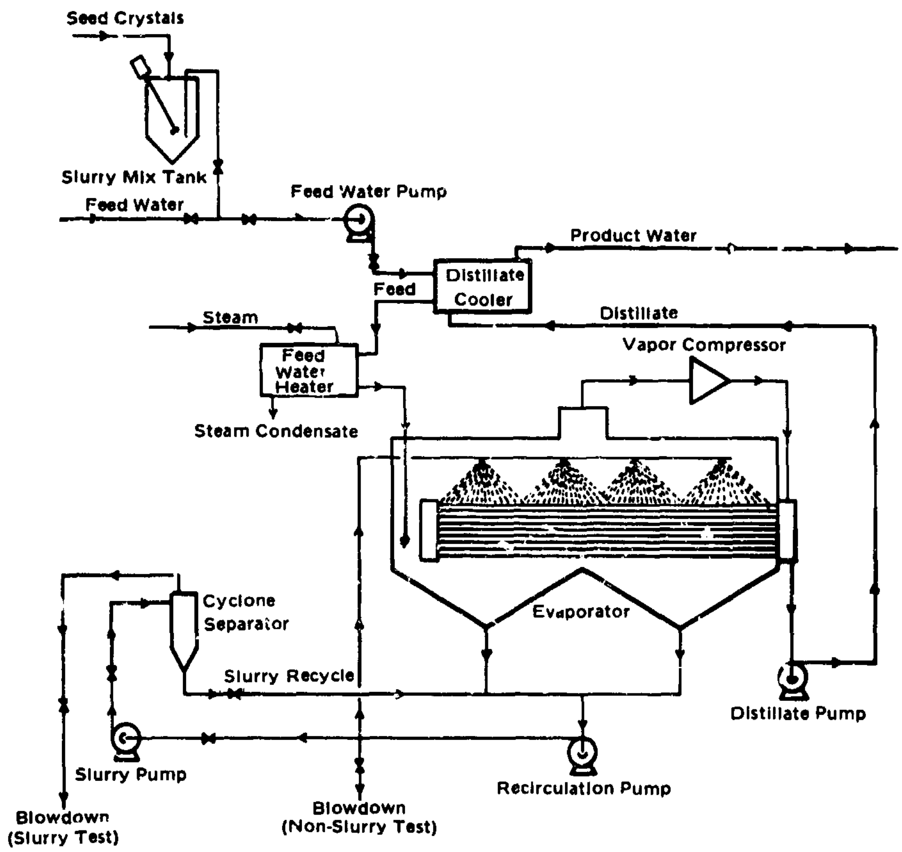

Fig. 2. Spray-film evaporator modified for crystal-seeding techniques.

Four pumps were used to service the unit: a feed pump to introduce the feed water to the heat exchangers and unit and draw in the seed crystals, a recirculation pump to recirculate the brine to the spray nozzles and draw back the separator underflow, a slurry pump to raise the pressure on the brine to accomplish separation in the slurry separators, and a distillate pump to pump the product through the distillate cooler and a portion of the product to desuperheat the compressed vapors.

The initial seed crystal addition for each test was made by dispersing 15 pounds of Snow White Filler No. 1 of the United States Gypsum Co. in 25 gallons of feed water and introducing it to the unit through the suction of the feed water pump (Fig. 3). Further seed additions were made as required using 10 pounds of filler in the 25 gallons of feed water.

4. **Test Procedures.** Manual controls were used to maintain operation of the unit. Control was accomplished by: Feed water heater steam pressure to introduce

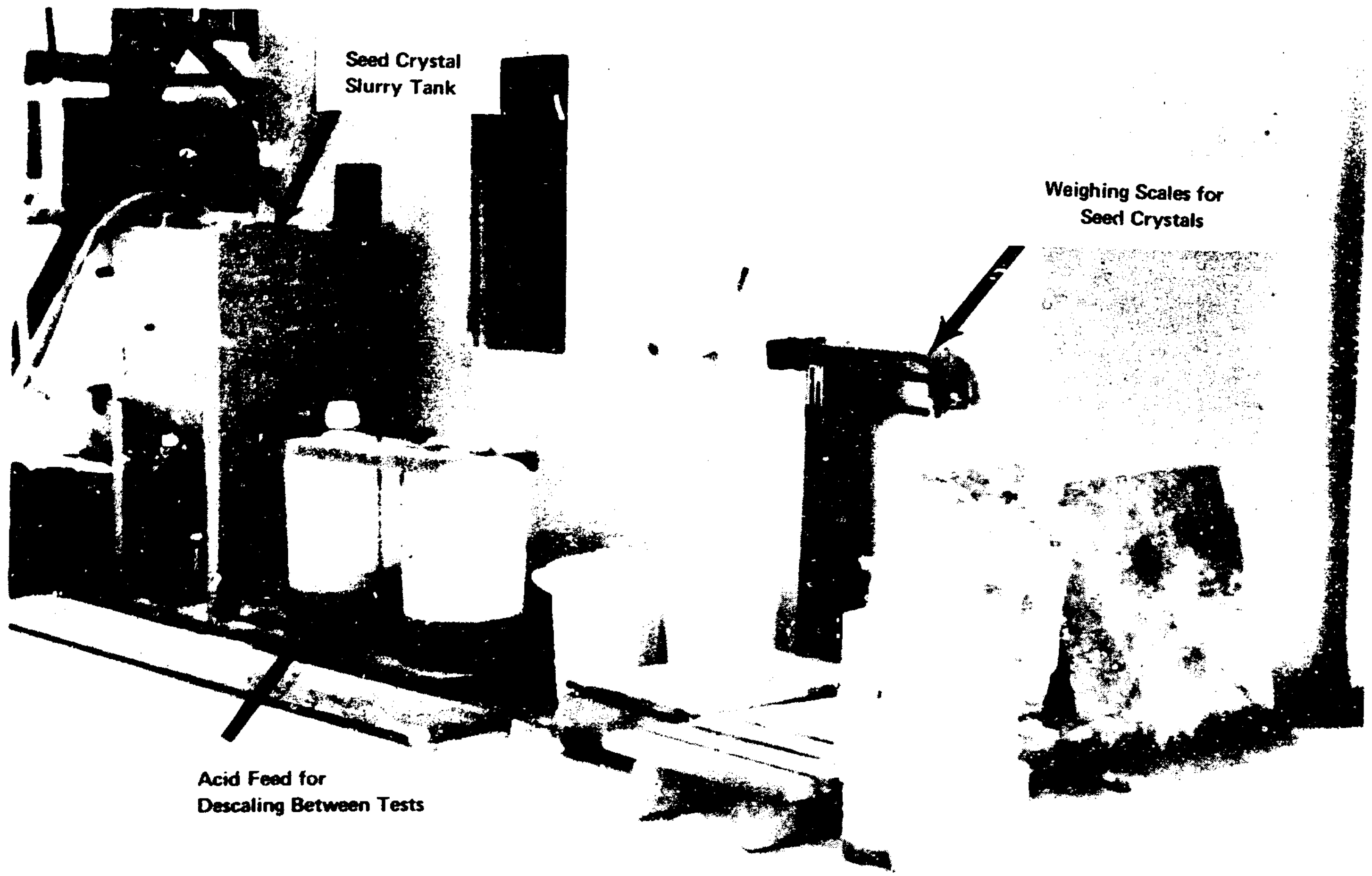

Fig. 3. Slurry addition apparatus.

the feed water to the unit at the proper temperature; blowdown flow adjustment to maintain the concentration factor of the recirculation brine at 3.5:1 to 4.0:1; and feed water flow adjustment to maintain the proper brine level in the evaporator.

The condition of the evaporator tube bundle before the test program is shown in Fig. 4. Acid to reduce alkaline scale formers was not added during the tests. The recirculation pump was operated without changing its flow rate of approximately 160 gpm through the spray nozzles.

Operating data on the unit was taken hourly on: The temperature of the recirculation brine, compressor discharge, water box outlet, and evaporator shell; the pressure of the compressor inlet and the compressor outlet; and the flow of the feed water, blowdown brine, and product water.

Samples were taken of the feed water, recycle brine, blowdown brine, and product water at approximately each 25 hours of operating time. These samples were analyzed for calcium, magnesium, sodium, sulfate, chloride, bicarbonate, carbonate, silica, total dissolved solids, alkalinity, hardness, pH, conductivity, and suspended solids. Scale samples taken from the evaporator tubes after each test and the suspended solids of slurry samples taken during Test A were analyzed for calcium, magnesium, sulfate, carbonate, and silica.

a. **Test A – Desalination of Silica-Removed Well Water Using Crystal-Seeding Techniques, 200-Hour Test.** Feed water which had been passed through the Johns-Manville Silica Removal process was used for the first 200-hour test. This feed water initially had a low silica content of about 0.9 ppm, but the silica content increased to 9.9 ppm at the end of the 200-hour test.

Fifteen pounds of seed crystals were initially added to the unit, followed by 10 pounds each 2 hours until a slurry was built up and retained by the unit, which was approximately 100 hours. Seeding was then reduced to 10 pounds each 4 hours until 120 hours and then 10 pounds each 8 hours of operation.

A shutdown of 40 hours was experienced at 14 hours of operation due to failure of the recirculation pump motor starter The unit was drained and flushed during the shutdown.

Shutdowns of 1½ to 2½ hours were also experienced at 96, 142, and 170 hours of operation to clean the feed water heater of alkaline scale and slurry accumulations. Other maintenance was carried out as required during these shutdowns.

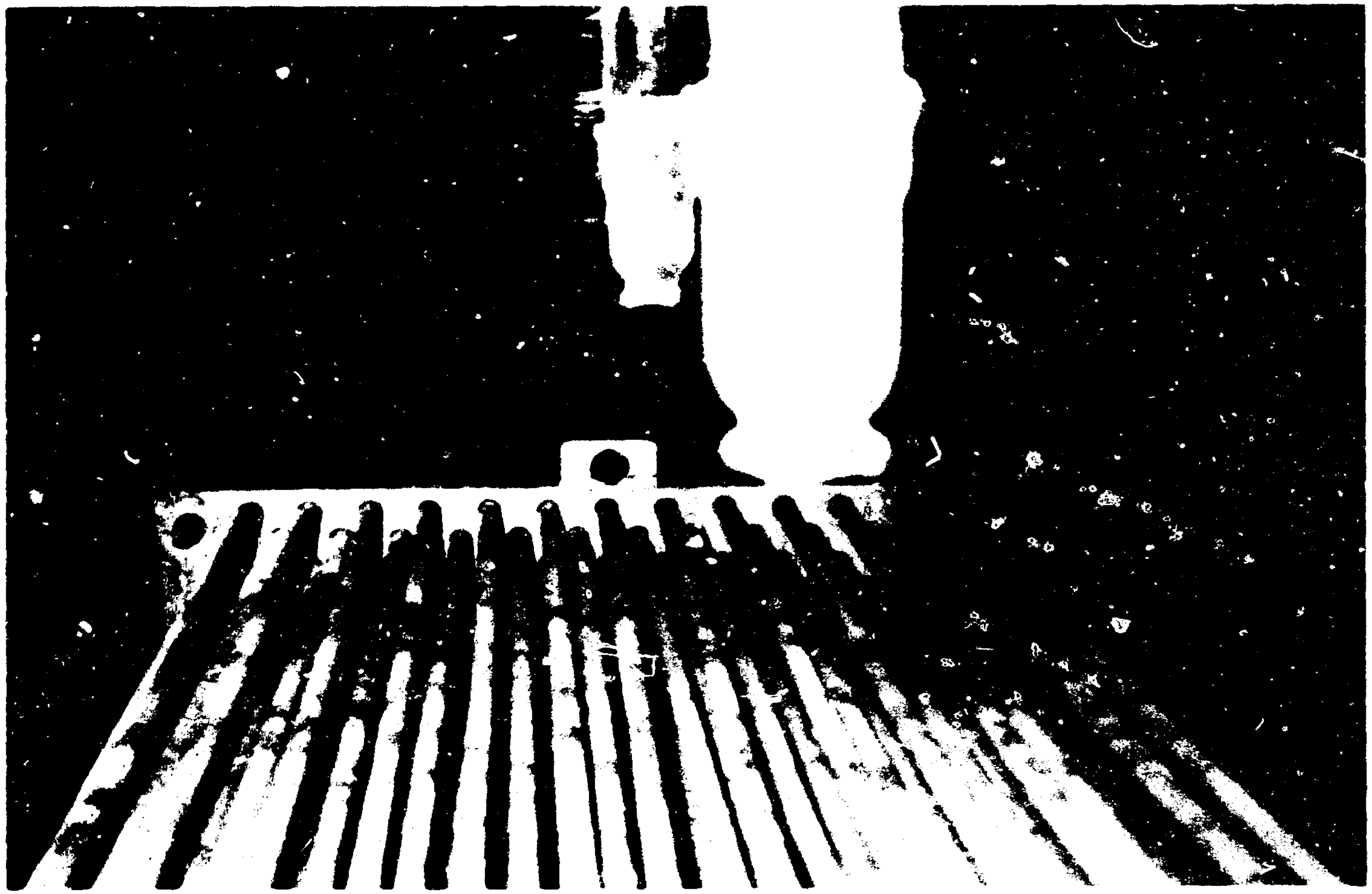

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Fig. 4. Evaporator tube bundle before test.

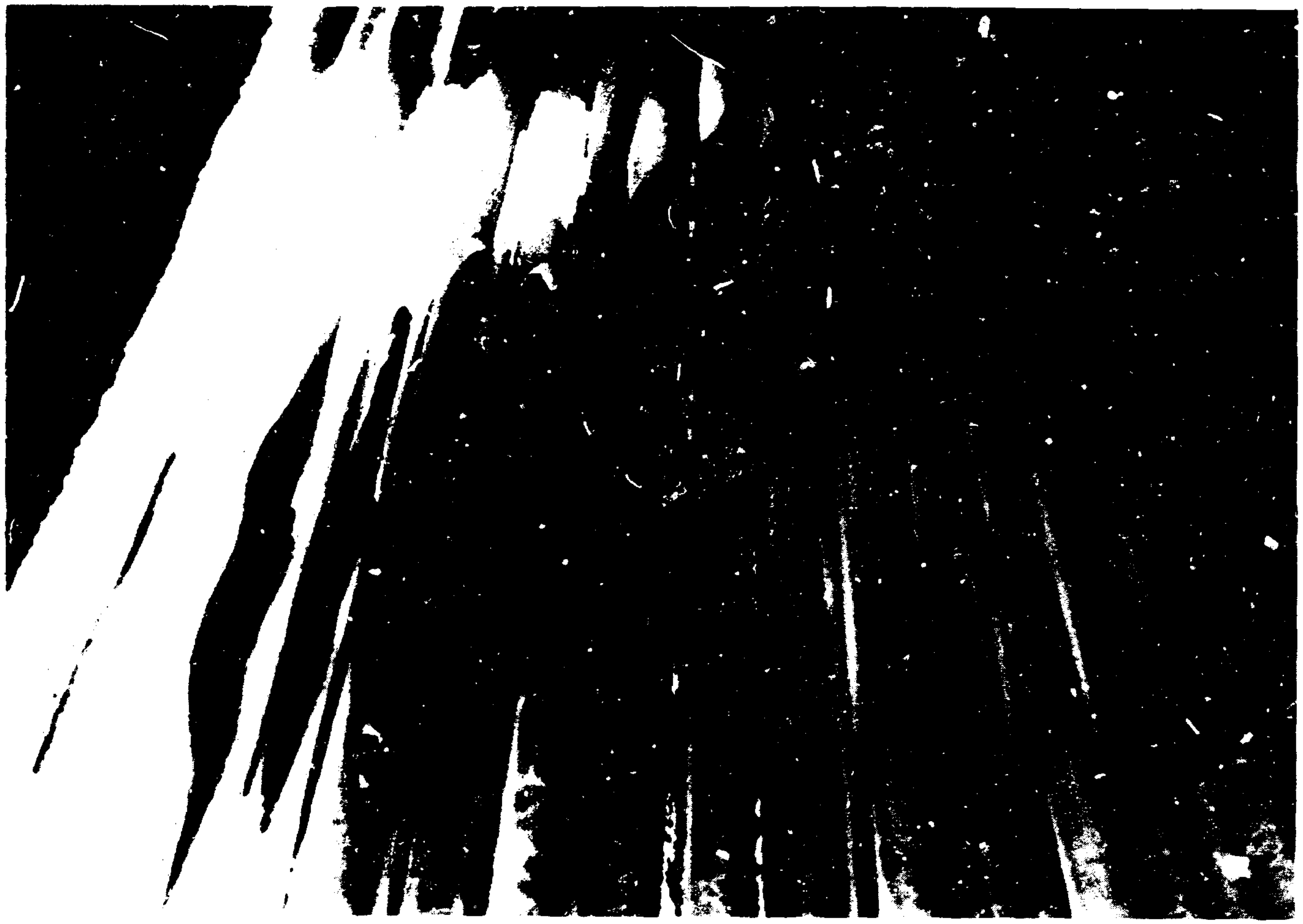

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Fig. 5. Evaporator tube bundle after Test A.

Figure 5 shows the condition of the evaporator tubes at the end of the 200-hour test. Table I indicates the average chemical analysis of the feed, recycle brine, blowdown brine and distillate during the test. Analysis of the scale formed on the tubes is shown in Table II. Slurry samples were analyzed and reported in Table III.

Descaling of the tubes was accomplished by using acid and tap water over a period of 13 hours. The feed water heater was cleaned mechanically and chemically.

Table I. Chemical Analysis – Test A
Silica-Removed Well Water with Crystal Seeding

Constituent	Feed	Recycle Brine	Blowdown Brine	Distillate
Calcium as Ca (ppm)	610	1582	1354	ND*
Magnesium as Mg (ppm)	173	646	665	ND
Sodium as Na (ppm)	4970	19000	19920	5
Sulfate as SO_4 (ppm)	1691	4262	3700	3
Chloride as Cl (ppm)	6434	30800	32300	6
Bicarbonate as HCO_3 (ppm)	213	30	28	3
Carbonate as $CaCO_3$ (ppm)	0	0	0	0
Silica as SiO_2 (ppm)	7.4	9.4	8.7	0.6
Total Dissolved Solids (ppm)	15520	56325	57960	16
p – Alkalinity as $CaCO_3$ (ppm)	0	0	0	0
m – Alkalinity as $CaCO_3$ (ppm)	174	24	23	2
Total Hardness as $CaCO_3$ (ppm)	2236	6610	6108	1
pH	7.5	8.2	8.1	6.3
Suspended Solids (ppm)	0	59300	2445	0

* ND – Not Detected

Table II. Scale Analysis

Constituent	Analysis (%)		
	Test A	Test B	Test C
Calcium as Ca	27.95	26.90	27.19
Magnesium as Mg	0.97	1.43	0.97
Sulfate as SO_4	68.21	67.16	66.92
Carbonate as CO_3	0.92	1.07	0.96
Silica (Sol) as SiO_2	ND*	ND	ND
Silica (Insol) as SiO_2	0.60	0.96	0.62

* ND – Not Detected

Table III. Slurry Analysis – Test A
Silica-Removed Well Water

Constituent	Analysis (%)	
	Recycle Slurry	Blowdown Slurry
Calcium as Ca	27.94	27.81
Magnesium as Mg	0.97	0.96
Sulfate as SO_4	65.19	65.85
Carbonate as CO_3	1.99	1.43
Silica (Insol) as SiO_2	0.18	0.18

b. **Test B – Desalination of Raw Well Water Using Crystal-Seeding Techniques, 200-Hour Test.** The raw well water was used for the second test using crystal-seeding techniques.

Fifteen pounds of seed crystals were initially added to the unit followed by 10 pounds each 2 hours until 42 hours of operation. Then seed crystals were added at 10 pounds each 8 hours. An additional 10 pounds were added at 80 hours because of low slurry content in the recycle brine. Part of the slurry was lost during a shutdown at 89 hours. Additions of 10 pounds at 89, 90, 91, and 95 did not bring the slurry content up. Additions of 10 pounds were made each 2 hours from 99 to 115 hours followed by 20-pound additions at 124, 125, and 139 hours before the slurry was restored. A 10-pound addition was made at 152 hours. At 177 hours, a power outage occurred for 2½ hours, during which the slurry was lost again. Crystal seed additions of 20 pounds at 178, 182, and 184 restored the slurry. The feed water heater was cleaned at 66, 87½, and 163 hours during shutdowns of 1 to 4½ hours. Other repairs were conducted at 87½ and 134 hours, the latter for 1½ hours.

At 187½ hours, the distillate pump seized due to a bearing failure. The test was terminated at this point because the pump could not be repaired or replaced quickly.

Figure 6 shows the condition of the evaporator tubes after the test. Table IV summarizes the average water conditions of the unit during the test. Table II reports the analysis of scale formed on the tubes during the test.

The descaling was done using cold tap water and acid for 17 hours, followed with heated tap water and acid for 18 hours.

c. **Test C – Desalination of Raw Well Water Without Crystal Seeding.** Due to the loss of the distillate pump, the slurry pump was piped to replace it. Because no slurry was used in this test the slurry pump was not needed.

Raw well water was used for this test; no acid or crystal seed were added. The unit was operated as much as possible under the same conditions as Tests A and B. The test was terminated when the compressor discharge pressure became excessive (over 19 inches Hg) at 21 hours of operation. During this test no shutdowns occurred because of feed water heater fouling or other maintenance requirements.

Table V summarizes the average water conditions of the unit during the test. Table II reports the analysis of the scale formed on the tubes during the test.

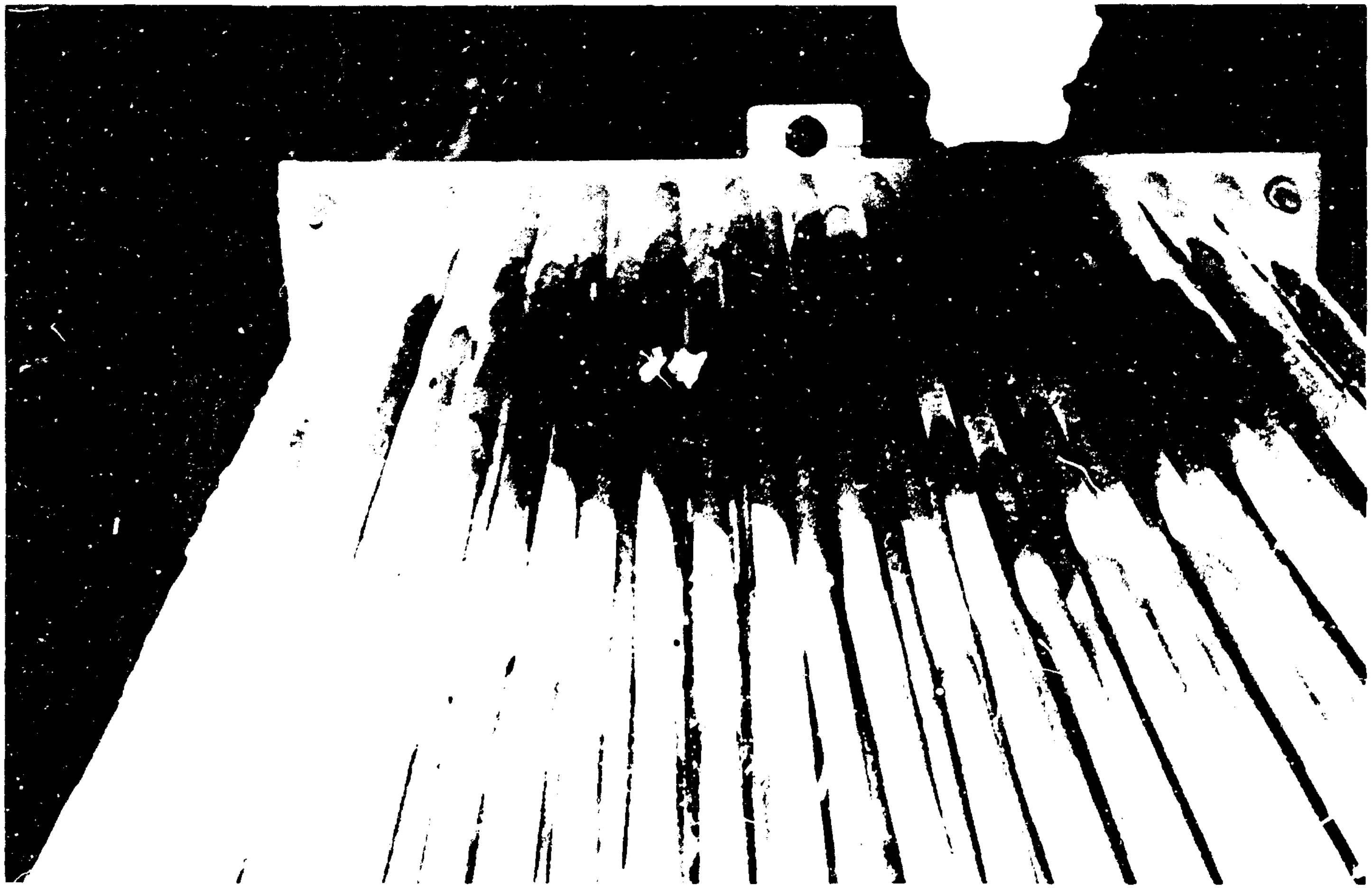

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Fig. 6. Evaporator tube bundle after Test B.

Table IV. Chemical Analysis – Test B
Raw Well Water with Crystal Seeding

Constituent	Feed	Recycle Brine	Blowdown Brine	Distillate
Calcium as Ca (ppm)	630	1780	1621	ND*
Magnesium as Mg (ppm)	169	676	624	<1
Sodium as Na (ppm)	4979	21,500	19,517	3
Sulfate as SO_4 (ppm)	1603	5633	4610	3
Chloride as Cl (ppm)	7991	34,100	31,333	2
Bicarbonate as HCO_3 (ppm)	202	25	42	1
Carbonate as $CaCO_3$ (ppm)	0	1	0	0
Silica as SiO_2 (ppm)	12.9	12.1	15.0	0.4
Total Dissolved Solids (ppm)	15,557	63,733	57,750	9
p – Alkalinity as $CaCO_3$ (ppm)	0	1	0	0
m – Alkalinity as $CaCO_3$ (ppm)	165	22	34	1
Total Hardness as $CaCO_3$ (ppm)	2267	7220	6603	<1
pH	7.36	8.32	7.90	5.9
Suspended Solids (ppm)	0	61,200	2340	0

* ND – Not Detected.

Table V. Chemical Analysis -- Test C
Raw Well Water without Crystal Seeding

Constituent	Feed	Blowdown Brine	Distillate
Calcium as Ca (ppm)	345	1533	1
Magnesium as Mg (ppm)	171	544	ND*
Sodium as Na (ppm)	4950	18,733	2
Sulfate as SO_4 (ppm)	1765	5027	6
Chloride as Cl (ppm)	7660	25,467	ND
Bicarbonate as HCO_3 (ppm)	198	33	1
Carbonate as $CaCO_3$ (ppm)	0	0	0
Silica as SiO_2 (ppm)	12.0	11.6	0.5
Total Dissolved Solids (ppm)	15,300	55,330	10
p – Alkalinity as $CaCO_3$ (ppm)	0	0	0
m – Alkalinity as $CaCO_3$ (ppm)	162	27	1
Total Hardness as $CaCO_3$ (ppm)	2060	6067	2
pH	7.29	7.73	5.54
Suspended Solids (ppm)	0	451	0

* ND – Not Detected.

III. DISCUSSION

5. **Discussion.** The evaporator tubes after tests using crystal seeding (Figs. 5 and 6) show significant areas where scaling was inhibited. These areas, approximately 20 by 20 inches under each spray nozzle, received an adequate spray of brine and crystal seeds. This unfouled area extended through the top five layers of the tube bundle. During the test without crystal seeding this area became fouled with evaporator scale.

Other areas of the evaporator tube bundle became encrusted with scale. Because of the inadequacy of the spray pattern, this encrusted scale could not be entirely removed by non-mechanical scale removing methods.

The heat transfer coefficients (Table VI and Fig. 7) indicate that the crystal-seeding technique inhibited the formation of evaporator scale at a ratio of approximately 10 to 1 when compared to the test when crystal seeding was not used. This ratio, however, is only an approximation because the data represent the overall heat transfer coefficient for the entire tube bundle. The tube area which did not receive an adequate brine spray had heavy fouling and added little to the overall heat transfer of the unit. This accounts for the relatively low heat transfer coefficient reported here as compared to the coefficients previously reported with this unit before modifications (3)(4).

Table VI. Heat Transfer Data
Heat Transfer Coefficient ($Btu/Hr\text{-}Ft^2\text{-}^oF$)

Operating Time (Hr)	Test A	Test B	Test C
1	886	531	555
5	1032	410	540
10	947	380	405
20	601	358	326
40	585	396	(b)
60	527	376	
80	555	362	
100	596	369	
120	461	377	
140	412	366	
160	443	311	
180	439	327	
200	408	(a)	

(a) Test terminated at 187.5 hours due to distillate pump failure.
(b) Test terminated at 21 hours due to excessive compressor discharge pressure.

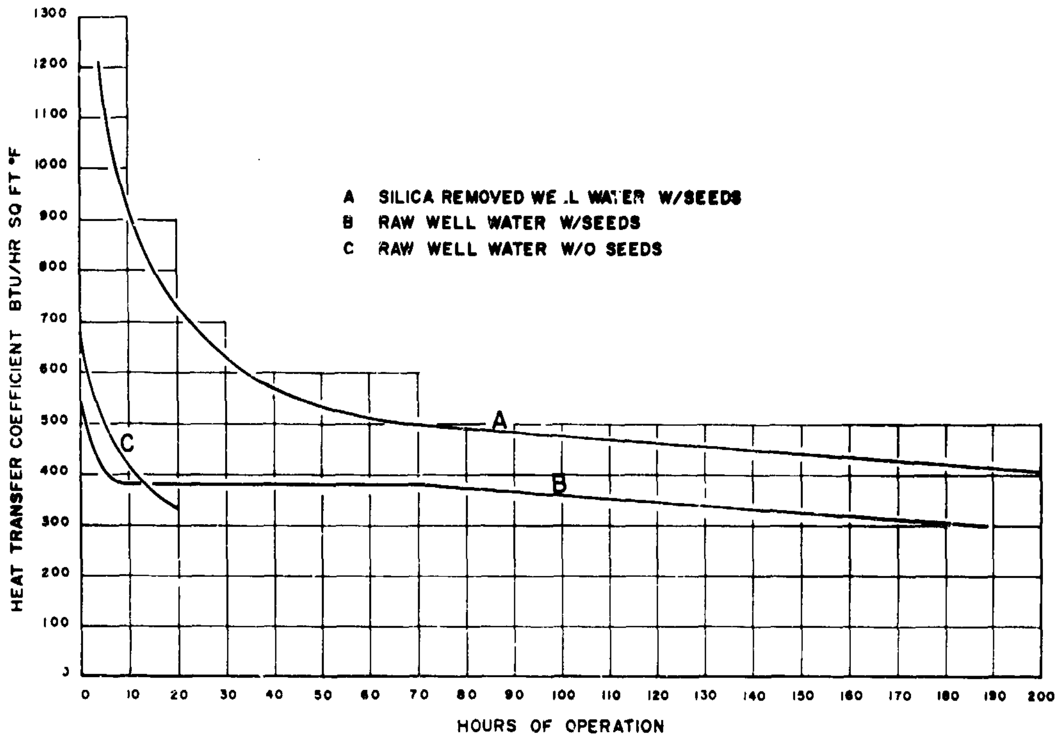

Fig. 7. Crystal-seeding technique in a spray-film evaporator using Roswell well water.

The sloping bottom of the evaporator kept the crystal seeds from depositing in the evaporator.

Acid was not used to control the alkaline scale formers in the feed water. The feed water heater was not designed to handle the seed crystals or use them effectively to prevent scale formation. Because of the resultant fouling, the feed water heater required cleaning often during the tests. The unit had to be shut down for this cleaning.

The slurry separators were not adequate for the task of keeping the initial crystal seed in the recycle brine. The particle size of the Snow White Filler No. 1 was too fine for effective separation from the brine. After the particles had grown for several hours under the evaporator conditions, they were retained satisfactorily.

Initial efforts to feed the crystal seeds using a gear-type pump were unsatisfactory because lumps in the Snow White Filler plugged the hose lines. Using the feed water pump suction proved satisfactory except when leaks developed in the plastic

piping which caused the pump to loose suction. A chemical pot-type feeder may be a better solution to this problem.

Piping modifications were made in lines which carried the slurry. If the flow stopped in any of these lines, they became plugged and had to be rodded. The cavities in valves became filled with slurry which caused them to become inoperative. All valves on slurry lines had to be replaced with gate valves (ball valves would have been better, but were not available), and all "ells" in the piping were replaced as much as possible with "tees" or "crosses." This was to facilitate rodding of the lines when they became plugged.

The output flow of the recirculation pump was not varied during the test program. The flow rate through each of the nozzles was approximately 41 gpm, or a total flow of 164 gpm.

The recirculation rate—the ratio of the brine recirculated to distillate produced—varied from 30.5:1 to 43.5:1 during these tests. This is significantly less than the 300:1 ratio for conventional brine in the tube forced circulation evaporators.

IV. CONCLUSIONS

6. **Conclusions.** It is concluded that:

a. Crystal-seeding techniques inhibit the formation of sulfate and alkaline scale in the horizontal-tube, spray-film evaporator.

b. Although the spray-film evaporator was properly designed to recirculate the crystal seeds without excess accumulations in the evaporator, the design of the spray pattern, tube bundle, and slurry separators were not adequate for the task.

c. Piping which carries the slurry must be fitted with ball valves, "tees," and "crosses" because the lines will require rodding whenever the flow stops.

d. The silica-removed well water caused scaling on the evaporator tubes.

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APPENDIX

DATA LOGGING AND CALCULATION PROCEDURE

A. A typical daily log data sheet is included as Fig. 8 and illustrates the data logged hourly.

The data logged each hour were as follows:

1. Time of data logging (hr).

2. Test time (hr) – accumulated time of the test.

3. T_1 Recirc (^oF) – recirculation temperature – thermometer in recirculation line discharge to shell.

4. T_2 Comp Dis (^oF) – temperature from compressor – dial thermometer at inlet to tube bundle.

5. T_3 Water Box Out (^oF) – distillate temperature leaving tube bundle – dial thermometer mounted in discharge tube bundle.

6. T_4 Shell (^oF) – shell temperature – thermometer mounted in evaporator shell vapor space.

7. P_1 Comp Suct (inches Hg) – compressor suction pressure – inches differential between atmospheric pressure and shell internal pressure as measured by 30-inch mercury manometer.

8. P_2 Comp Disch (inches Hg) – compressor discharge pressure – inches differential between atmospheric pressure and compressor discharge pressure as measured by mercury manometer.

9. P_3 Comp Diff (inches Hg) – compressor differential pressure – inches differential between shell internal pressure and compressor discharge pressure at inlet to waterbox as measured by mercury manometer.

10. Feed Rotameter – direct reading of feed rotameter in gpm.

11. Distillate Flow – time for 9½ quarts as measured by a bucket and a stopwatch.

12. Blowdown Rate – similar to item 11.

B. A typical calculation data sheet is included as Fig. 9.

Calculation procedure used:

1. Test – description of test conditions.

2. Date – day of the observation.

3. Time – hour of the observation.

4. Test Time (hr) – accumulated time of the test.

5. Barometer (inches Hg) – absolute barometer pressure.

6. Suction Press Rdg (inches Hg) – item 7, data sheet (Fig. 8).

7. Correction (inches Hg) – correction for water legs in the manometer.

8. Suction Press Time (inches Hg) – item 5 minus item 6.

9. Suction Press Absolute (inches Hg) – item 4 plus item 7.

10. Suction Temperature (^{O}F) – Keenan & Keyes Steam Table Saturate Temperature for item 8.

11. Discharge Press Rdg (inches Hg) – item 8, Data Sheet (Fig. 8).

12. Correction (inches Hg) – correction for water legs in manometer.

13. Discharge Press Time (inches Hg) – item 11 minus item 12.

14. Discharge Press Absolute (inches Hg) – item 4 plus item 13.

15. Discharge Temp (^{O}F) – steam tables saturated temperature for item 14.

16. Temp dif (^{O}F) (apparent) – item 15 minus item 10.

17. Adiabatic Compression (Btu/lb) – adiabatic work of compression obtained from Mollier Diagram as the adiabatic compression going from item 10 to item 15.

18. Compression Work (Btu/lb) – adiabatic compression, item 17, divided by the compression adiabatic efficiency (59%).

19. Latent Heat T_2 (Btu/lb) – latent heat of condensation at compression discharge temperature, item 15.

20. Corrected Tube Bundle Latent Heat (Btu/lb) – compressor work, item 18, plus latent heat T_2, item 19.

21. Distillate Reading (sec) – time to fill 9½-qt bucket – Data Sheet (Fig. 8), item 11.

22. Distillate Flow (lb/hr) – 70540 divided by distillate reading, item 21.

23. Heat Transfer (Btu/hr) – bundle heat transfer (Btu/lb) item 20 multiplied by item 22.

24. Heat Flux (Btu/hr-ft^2) – heat transfer, item 23, divided by the heat transfer area, 268 ft^2.

25. Heat Transfer Coefficient (Btu/hr-ft^2-^{o}F) – heat flux, item 24, divided by temperature difference (apparent), item 16.

26. Boiling Point Elevation (^{o}F) – obtained from Fig. 10. BPE vs Chlorosity based on blowdown concentration.

27. Temperature Difference (corr) – item 16 minus item 26.

28. Heat Transfer Coefficient (corr) – heat flux, item 24, divided by temperature difference (corr), item 27.

29. Recirculation Flow – based on pressure in recirculation line on the 4 spray nozzles – 164 gpm or 82,902 lb/hr.

30. Recirculation Ratio – lb recirculated per lb product, item 29 divied by item 22.

SAMPLE DATA SHEET

DATE ________________ OPERATORS ______________________

1. Time of Observation ____ ____ ____ ____ ____ ____ ____ ____

2. Test Time ____ ____ ____ ____ ____ ____ ____ ____
   Temperature (^{o}F)

3. Recirculation Line ____ ____ ____ ____ ____ ____ ____ ____

4. Compressor Discharge ____ ____ ____ ____ ____ ____ ____ ____

5. Water Box Outlet ____ ____ ____ ____ ____ ____ ____ ____

6. Evaporator Shell ____ ____ ____ ____ ____ ____ ____ ____
   Pressure (in. Hg)

7. Compressor Suction ____ ____ ____ ____ ____ ____ ____ ____

8. Compressor Discharge ____ ____ ____ ____ ____ ____ ____ ____
   Pressure Difference (in. Hg)

9. Compressor Flow ____ ____ ____ ____ ____ ____ ____ ____

10. Feed (Rotameter gpm) ____ ____ ____ ____ ____ ____ ____ ____

11. Distillate (min:sec) ____ ____ ____ ____ ____ ____ ____ ____

12. Blowdown (min:sec) ____ ____ ____ ____ ____ ____ ____ ____

REMARKS:

Fig. 8. Sample data sheet.

SAMPLE CALCULATION SHEET

1. Test								
2. Date								
3. Time								
4. Test Time								
5. Barometer								
6. Comp Suct (Abs)								
7. Correction								
8. Comp Suct (True)								
9. Comp Suct (Abs)								
10. Comp Suct Temp								
11. Comp Disch (Abs)								
12. Correction								
13. Comp Disch (True)								
14. Comp Disch (Abs)								
15. Comp Disch Temp								
16. Temp Dif (app)								
17. Adiabatic Comp								
18. Comp Work								
19. Latent Heat								
20. Latent Heat (corr)								
21. Distillate Rdg								
22. Dist Flow Rate								
23. Heat Transfer								
24. Heat Flux								
25. HTC (app)								
26. BPE								
27. Temp Dif (corr)								
28. HTC (corr)								
29. Recirc Flow								
30. Recirc Ratio								

Fig. 9. Sample calculation sheet.

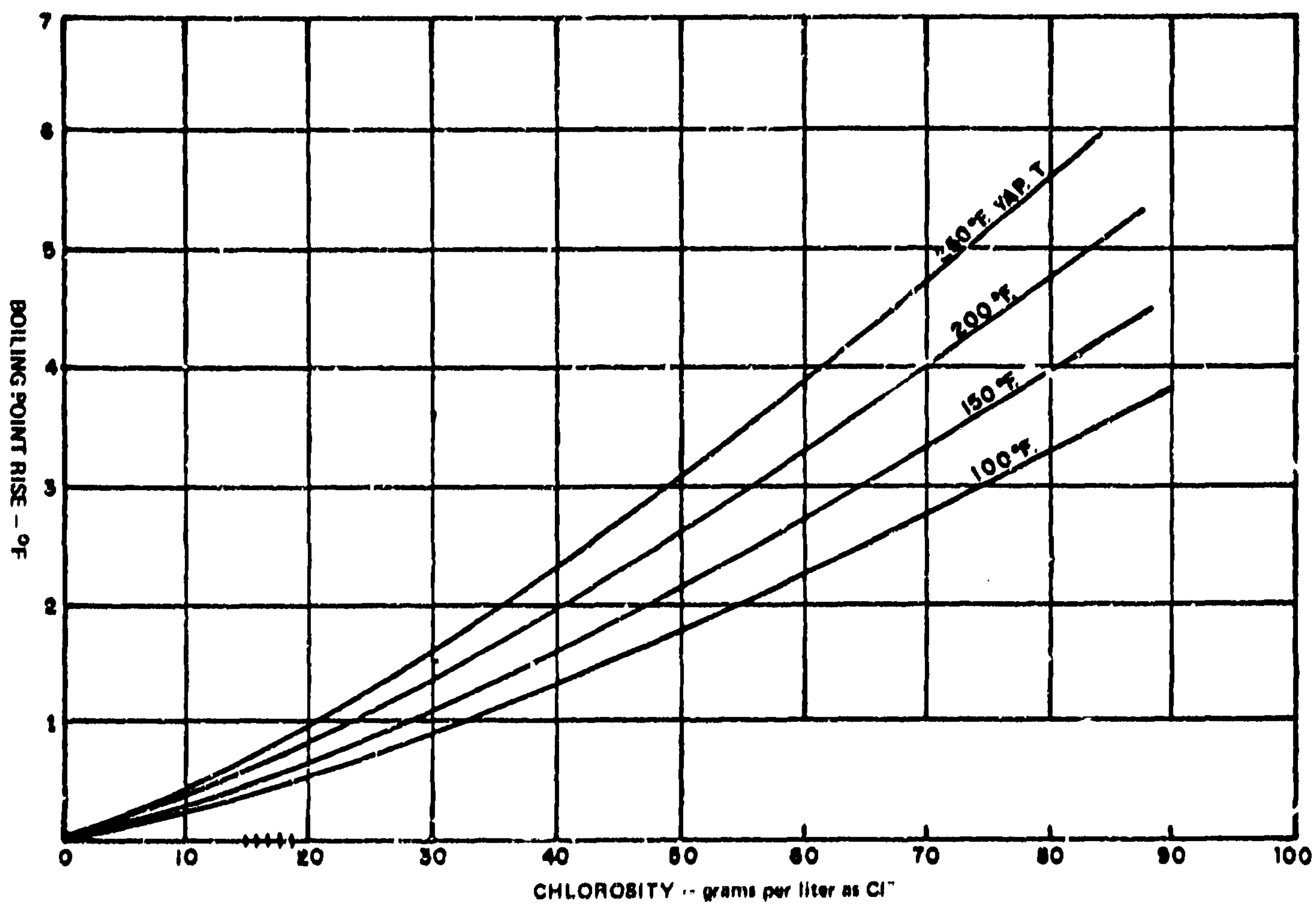

Fig. 10. Boiling point rise of sea water concentrates.

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13. ABSTRACT

When operating on many brackish waters, sea water distillation equipment becomes inoperative in a short time because of heavy deposits of calcium sulfate scale. Investigations are being made to evaluate a calcium sulfate crystal-seeding method for prevention of this scale formation in evaporators. This report covers tests performed at the Office of Saline Water, Roswell Test Facility to investigate the use of crystal-seeding techniques to inhibit the formation of sulfate scale in a horizontal-tube, spray-film evaporator. These crystal-seeding techniques were evaluated on raw well water and well water with silica removed. A control test without crystal seeding was also conducted. The results of these tests indicate that on all waters tested, the crystal-seeding process can inhibit the formation of evaporator scale in a horizontal-tube, spray-film evaporator.

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